CLAIMS

1. A method of detecting ice comprising:

forming an acoustic wave cavity in a substrate;

generating an acoustic wave substantially trapped in an acoustic wave cavity wherein the acoustic wave in the cavity is sensitive to ice and insensitive to water;

providing a signal representative of the acoustic wave in the acoustic wave cavity; and

detecting the presence of ice on the acoustic wave cavity from the signal.

2. A method of detecting ice comprising:

generating a torsional acoustic wave substantially trapped in an acoustic wave cavity formed in a noncylindrical substrate, the presence of ice on a surface of the acoustic wave cavity producing a detectable change in the torsional acoustic wave; and

detecting the change in the torsional acoustic wave indicative of the presence of ice on a surface of the acoustic wave cavity.

3. A method of detecting ice comprising:

forming an acoustic wave cavity in a substrate defined by an area of increased mass;

generating a torsional acoustic wave substantially trapped in an acoustic wave cavity, the presence of ice on a surface of the acoustic wave cavity producing a detectable change in the torsional acoustic wave; and

detecting the change in the torsional acoustic wave indicative of the presence of ice on a surface of the acoustic wave cavity.

4. A method of detecting water and ice comprising:

generating an acoustic wave substantially trapped in an acoustic wave cavity wherein the acoustic wave in the cavity is insensitive to water and sensitive to ice;

providing a signal representative of the water insensitive acoustic wave in the acoustic wave cavity;

comparing the signal representing the water insensitive acoustic wave to a reference to detect the presence of ice on the acoustic wave cavity;

generating another acoustic wave substantially trapped in an acoustic wave cavity wherein the other acoustic wave is sensitive to water;

providing a signal representative of the water sensitive acoustic wave in the acoustic wave cavity; and

comparing the signal representing the water sensitive acoustic wave to a reference to detect the presence of water on the acoustic wave cavity.

5. A method of detecting water and ice comprising:

generating, in a first mode of operation, an acoustic wave substantially trapped in an acoustic wave cavity wherein the acoustic wave in the cavity is insensitive to water and sensitive to ice;

providing a signal representative of the water insensitive acoustic wave in the acoustic wave cavity;

generating, in a second mode of operation, another acoustic wave substantially tapped in an acoustic wave cavity wherein the other acoustic wave is sensitive to water;

providing a signal representative of the water sensitive acoustic wave in the acoustic wave cavity;

comparing the signal representing the water insensitive acoustic wave to a reference to detect the presence of ice on the acoustic wave cavity; and

comparing the signal representing the water sensitive acoustic wave to a reference to detect the presence of water on the acoustic wave cavity.

6. A method of detecting water and ice comprising:

positioning a plurality of transducers with respect to an acoustic wave cavity;

driving a first set of the transducers to generate an acoustic wave in the acoustic wave cavity wherein the acoustic wave in the cavity is sensitive to ice and insensitive to water;

providing a signal representing the acoustic wave generated by the first set of transducers;

driving a second set of the transducers to generate an acoustic wave in the acoustic wave cavity wherein the acoustic wave in the cavity is sensitive to water;

providing a signal representing the acoustic wave generated by the second set of transducers; and

analyzing the signals representing acoustic waves generated by the first and second sets of transducers to detect the presence of ice and/or water.

7. A method of distinguishing the presence of different substances on an acoustic wave sensor comprising:

generating, in a first mode of operation, a first acoustic wave substantially trapped in an acoustic wave cavity formed in the sensor, the first acoustic wave being sensitive to a first substance on the acoustic wave cavity;

generating, in a second mode of operation, a second acoustic wave, different from the first acoustic wave, substantially trapped in the acoustic wave cavity formed in the sensor, the second acoustic wave being sensitive to a second substance on the acoustic wave cavity; and

analyzing the response of the first and second acoustic waves to determine the presence of the first and/or second substances on the acoustic wave cavity.

8. A method as recited in claim 7 wherein the steps of generating the first and second acoustic waves in the acoustic wave cavity includes driving a first set of transducers positioned with respect to the acoustic wave cavity to generate the first acoustic wave and driving a second set of transducers positioned with respect to the acoustic wave cavity to generate the second acoustic wave.

9. A method as recited in claim 8 wherein the transducers in the first and second sets are different.

10. A method as recited in claim 8 wherein at least one of the transducers in the first set is not in the second set.

11. A method as recited in claim 8 wherein at least one of the transducers in the second set is not in the first set.

12. A method of distinguishing the presence of different substances on an acoustic wave sensor comprising:

positioning a plurality of transducers with respect to an acoustic wave cavity;

driving a first set of the transducers to generate in the acoustic wave cavity a first acoustic wave that is responsive to the presence of a first substance on the acoustic wave cavity;

providing a signal representing the first acoustic wave in the acoustic wave cavity;

driving a second set of the transducer to generate in the acoustic wave cavity a second acoustic wave that is responsive to the presence of a second substance on the acoustic wave cavity;

providing a signal representing the second acoustic wave in the acoustic wave cavity; and

analyzing the signals representing the first and second acoustic waves to detect the presence or absence of the first or second substances.

13. A method of detecting ice and water on a substrate comprising:

generating a torsional acoustic wave substantially trapped in an acoustic wave cavity formed in the substrate;

generating an acoustic wave other than a torsional acoustic wave in the acoustic wave cavity, the other acoustic wave being sensitive to water;

analyzing the response of the torsional acoustic wave and the other acoustic wave to determine the presence of ice and/or water.

14. A method as recited in claim 13 wherein the other acoustic wave generated includes shear wave components.

15. A method as recited in claim 13 wherein the other acoustic wave generated includes a flexural mode.

16. A method of detecting ice and water comprising:

positioning a first acoustic wave transducer centered on an acoustic wave cavity;

positioning a second acoustic wave transducer adjacent the acoustic wave cavity but off center with respect thereto;

driving the first acoustic wave transducer to generate in the acoustic wave cavity a first acoustic wave that is responsive to water;

driving the second acoustic wave transducer to generate in the acoustic wave cavity a second acoustic wave that is responsive to ice; and

analyzing the first and second acoustic waves to determine the presence of water and/or ice.

17. A method as recited in claim 16 including positioning a third acoustic wave transducer adjacent the acoustic wave cavity but off center with respect thereto wherein the third acoustic wave transducer is driven with the second acoustic wave transducer to generate in the acoustic wave cavity an acoustic wave that is responsive to ice.

18. A method of detecting the presence of different substances on an acoustic wave cavity formed in a substrate comprising:

positioning a first acoustic wave transducer adjacent the acoustic wave cavity but off center with respect thereto;

positioning a second acoustic wave transducer adjacent the acoustic wave cavity but off center with respect thereto;

driving the first acoustic wave transducer to generate a first acoustic wave responsive to a first substance on the acoustic wave cavity;

driving the first and second acoustic wave transducers to generate a second, different acoustic wave responsive to a second substance on the acoustic wave cavity; and

analyzing the first and second acoustic waves to determine the presence of the first and/or second substance.

19. A method of distinguishing the presence of different substances on an acoustic wave sensor comprising:

generating a first acoustic wave substantially trapped in an acoustic wave cavity formed in the sensor, the first acoustic wave having circular nodal lines and being sensitive to a first substance on the acoustic wave cavity;

generating a second acoustic wave substantially trapped in the acoustic wave cavity, the second acoustic wave having linear, parallel nodal lines and being sensitive to a second substance on the acoustic wave cavity; and

analyzing the response of the first and second acoustic waves to determine the presence of the first and/or second substances on the acoustic wave cavity.

20. A method as recited in claim 19 wherein the steps of generating the first and second acoustic waves in the acoustic wave cavity includes driving a first set of transducers positioned with respect to the acoustic wave cavity to generate the first acoustic wave and driving a second set of transducers positioned with respect to the acoustic wave cavity to generate the second acoustic wave.

21. A method as recited in claim 20 wherein the transducers in the first and second sets are different.

22. A method as recited in claim 20 wherein at least one of the transducers in the first set is not in the second set.

23. A method as recited in claim 20 wherein at least one of the transducers in the second set is not in the first set.

24. An ice detector comprising:

an acoustic wave cavity formed in a substrate and defined by an area of increased mass;

at least one transducer positioned adjacent to the acoustic wave cavity, the transducer when driven generating an acoustic wave trapped in the acoustic wave cavity, the acoustic wave being sensitive to the presence of ice on the acoustic wave cavity and insensitive to water on the acoustic wave cavity, and the transducer providing a signal representing the acoustic wave in the acoustic wave cavity; and

a circuit responsive to the transducer signal to detect the presence of ice.

25. An ice detector as recited in claim 24 wherein the acoustic wave generated and trapped in the acoustic wave cavity is a torsional wave.

26. An ice detector as recited in claim 25 wherein the acoustic wave cavity has a planar surface and the transducer lies in a plane that is parallel to the planar surface.

27. An ice detector as recited in claim 24 wherein the transducer is a piezoelectric transducer mounted on a surface of the acoustic wave cavity off center with respect to the center of the cavity.

28. An ice detector as recited in claim 27 wherein the acoustic wave cavity is defined by an area of increased mass having a

generally circular periphery and the transducer is positioned at a right angle to a radius of the cavity.

29. An ice detector as recited in claim 24 including at least two transducers positioned on opposite sides of a centerline of the cavity for generating the acoustic wave.

30. An ice detector as recited in claim 29 wherein the transducers are electro-magnetic transducers.

31. An ice detector as recited in claim 24 wherein the transducer is an electro-magnetic transducer positioned off center with respect to a centerline of the acoustic wave cavity.

32. An ice detector as recited in claim 24 wherein the circuit includes a comparator for comparing a value representing the acoustic wave signal to a reference to detect the presence of ice.

33. An ice detector as recited in claim 32 wherein the value represents a period of time the acoustic wave decays to a predetermined level.

34. An ice detector comprising:

an acoustic wave cavity formed in a substrate and defined by an area of increased mass;

at least one transducer positioned adjacent the acoustic wave cavity, the transducer when driven generating in the acoustic wave cavity a torsional acoustic wave that is sensitive to ice, the transducer providing a signal representing the torsional acoustic wave in the acoustic wave cavity; and

a circuit responsive to the transducer signal to detect the presence of ice.

35. An ice detector as recited in claim 34 wherein the acoustic wave cavity has a planar surface and the transducer lies in a plane that is parallel to the planar surface.

36. An ice detector as recited in claim 35 wherein the transducer is a piezoelectric transducer mounted on a surface of the acoustic wave cavity off center with respect to the center of the cavity.

37. An ice detector as recited in claim 36 wherein the acoustic wave cavity is defined by an area of increased mass having a generally circular periphery and the transducer is position at a right angle to a radius of the cavity.

38. An ice detector as recited in claim 35 including at least two transducers positioned on opposite sides of a centerline of the cavity for generating the acoustic wave.

39. An ice detector as recited in claim 38 wherein the transducers are electro-magnetic transducers.

40. An ice detector as recited in claim 35 wherein the transducer is an electro-magnetic transducer positioned off center with respect to a centerline of the acoustic wave cavity.

41. An ice detector as recited in claim 35 wherein the circuit includes a comparator for comparing a value representing the acoustic wave signal to a reference to detect the presence of ice.

42. An ice detector as recited in claim 41 wherein the value represents a period of time the acoustic wave decays to a predetermined level.

43. An acoustic wave resonator comprising:

an acoustic wave cavity formed in a substrate and defined by an area of increased mass;

a plurality of transducers positioned adjacent an acoustic wave cavity;

a controller coupled to the transducers, the controller driving a first set of transducers to generate a first acoustic wave in the acoustic wave cavity and the controller driving a second set of the transducers to generate a second acoustic wave in the cavity.

44. An acoustic wave resonator as recited in claim 43 wherein at least one of the transducers is centered on a centerline of the acoustic wave cavity.

45. An acoustic wave resonator as recited in claim 43 wherein at least one of the transducers is positioned off center with respect to a centerline of the cavity.

46. An acoustic wave resonator as recited in claim 43 wherein the plurality of the transducers includes at least two transducers positioned off center with respect to a centerline of the cavity and wherein the first set of transducers includes one of the off center transducers and the second set of transducers includes the two off center transducers.

47. An acoustic wave resonator as recited in claim 43 wherein the transducers in the first and second sets are different.

48. An acoustic wave resonator as recited in claim 43 wherein at least one of the transducers in the first set is not in the second set.

49. An acoustic wave resonator as recited in claim 43 wherein the polarity of at least one of the transducers in the first set is different from the polarity of the transducers in the second set.

50. An acoustic wave resonator as recited in claim 43 wherein at least one of the transducers in the second set is not in the first set.

51. An acoustic wave sensor comprising:

an acoustic wave cavity formed in a substrate and defined by an area of increased mass;

a plurality of transducers positioned adjacent the acoustic wave cavity;

a controller coupled to the transducers, the controller driving a first set of the transducers to generate a first acoustic wave in the acoustic wave cavity, the first acoustic wave being sensitive to a first event and the controller driving a second set of transducers to generate a second acoustic wave in the cavity, the second acoustic wave being sensitive to a second event.

52. An acoustic wave sensor as recited in claim 51 wherein at least one of the transducers is centered on a centerline of the acoustic wave cavity.

53. An acoustic wave sensor as recited in claim 51 wherein at least one of the transducers is positioned off center with respect to a centerline of the cavity.

54. An acoustic wave sensor as recited in claim 51 wherein the plurality of the transducers includes at least two transducers positioned off center with respect to a centerline of the cavity and wherein the first set of transducers includes one of the off center transducers and the second set of transducers includes the two off center transducers.

55. An acoustic wave sensor as recited in claim 51 wherein the transducers in the first and second sets are different.

56. An acoustic wave sensor as recited in claim 51 wherein at least one of the transducers in the first set is not in the second set.

57. An acoustic wave sensor as recited in claim 51 wherein the polarity of at least one of the transducers in the first set is different from the polarity of the transducer in the second set.

58. An acoustic wave sensor as recited in claim 51 wherein at least one of the transducers in the second set is not in the first set.

59. An acoustic wave ice and water sensor comprising:

an acoustic wave cavity formed in a substrate and defined by an area of increased mass;

a plurality of transducers positioned adjacent the acoustic wave cavity including at least one transducer positioned off center with respect to a centerline of the cavity;

a controller coupled to the transducers, the controller driving a first set of the transducers including one off center transducer to generate a first acoustic wave in the acoustic wave cavity, the first acoustic wave being sensitive to ice and the controller driving a second set of transducers to generate a second acoustic wave in the acoustic wave cavity, the second acoustic wave being sensitive to water.

60. An acoustic wave ice and water sensor as recited in claim 59 wherein the first acoustic wave is a torsional acoustic wave.

61. An acoustic wave ice and water sensor as recited in claim 59 wherein the second acoustic wave is a shear wave.

62. An acoustic wave ice and water sensor as recited in claim 59 wherein the second set of transducers includes a transducer centered on the center of the acoustic wave cavity.

63. An acoustic wave ice and water sensor as recited in claim 59 wherein the second set of transducers includes the one off center transducer and a second off center transducer.

64. An acoustic wave ice and water sensor as recited in claim 63 wherein the polarity of the one off center transducer is in the same direction as the polarity of the second off center transducer, the one and second off centered transducers being positioned on opposite sides of a centerline of the acoustic wave cavity.

65. An acoustic wave ice and water sensor as recited in claim 59 wherein the first set of transducers includes at least one other off center transducer.

66. An acoustic wave ice and water sensor as recited in claim 59 wherein the controller is responsive to the receipt of a signal from at least one transducer in the first set for detecting the presence of ice and the controller is responsive to the receipt of a signal from at least one transducer in the second set for detecting the presence of water.

67. An acoustic wave ice and water sensor as recited in claim 66 wherein the controller switches from driving the first set of transducers to driving the second set of transducers after detecting the presence or absence of ice on the acoustic wave cavity.

68. An acoustic wave ice and water sensor as recited in claim 66 wherein the controller switches from driving the second set of transducers to driving the first set of transducers after detecting the presence or absence of water on the acoustic wave cavity.

69. An acoustic wave ice and water sensor as recited in claim 59 wherein the acoustic wave cavity is formed in a substrate that is an insert for mounting in an aperture of a structure.

70. An acoustic wave ice and water sensor as recited in claim 59 wherein the structure is an insert support having threads on a portion of an outer surface thereof.

71. An acoustic wave ice and water sensor as recited in claim 59 wherein the structure is a member of a device for which ice detection is desired.

72. An ice detector for a structure comprising:

an acoustic wave cavity formed in a substrate, the substrate being an insert for mounting in an aperture of the structure;

at least one transducer mounted adjacent the acoustic wave cavity, the transducer when driven generating an acoustic wave trapped in the acoustic wave cavity, the acoustic wave being sensitive to the presence of ice on a surface of the acoustic wave cavity and the transducer providing a signal representing the acoustic wave in the acoustic wave cavity; and

a circuit responsive to the transducer signal to detect the presence of ice on a surface of the acoustic wave cavity.

73. An ice detector as recited in claim 72 wherein the substrate is a first insert mounted in a support, the support forming a second insert for mounting in the aperture of the structure.

74. An ice detector as recited in claim 73 wherein the support includes a head portion with an aperture therein for receiving the substrate with the acoustic wave cavity and the support having a body extending from the head portion, the body extending through the aperture of the structure when mounted therein.

75. An ice detector as recited in claim 74 wherein the body includes threads on at least an outer portion thereof.

76. An ice detector as recited in claim 74 wherein the body is hollow and the transducers are mounted in the hollow portion of the body.

77. An ice detector as recited in claim 76 wherein at least a portion of the circuit is mounted in the hollow portion of the body.

78. An ice detector as recited in claim 72 wherein the insert includes a head portion in which the acoustic wave cavity is formed and the insert has a body extending from the head portion, the body extending through the aperture of the structure when mounted therein.

79. An ice detector as recited in claim 78 wherein the body includes threads on at least an outer portion thereof.

80 An ice detector as recited in claim 78 wherein the body is hollow and the transducers are mounted in the hollow portion of the body.

81. An ice detector as recited in claim 78 wherein at least a portion of the circuit is mounted in the hollow portion of the body.

82. An ice and water detector comprising:

an acoustic wave cavity formed in a substrate and defined by an area of increased mass;

a plurality of transducers positioned adjacent the acoustic wave cavity, a first set of the transducers when driven generating in the acoustic wave cavity, a first acoustic wave that is sensitive to ice on a surface of the acoustic wave cavity and insensitive to water on a surface of the acoustic wave cavity and a second set of the transducers when driven generating in the acoustic wave cavity, a second acoustic wave that is sensitive to water;

a controller responsive to signals respectively representing the first and second acoustic waves in the acoustic wave cavity to determine the presence of ice and/or water on a surface of the acoustic wave cavity.